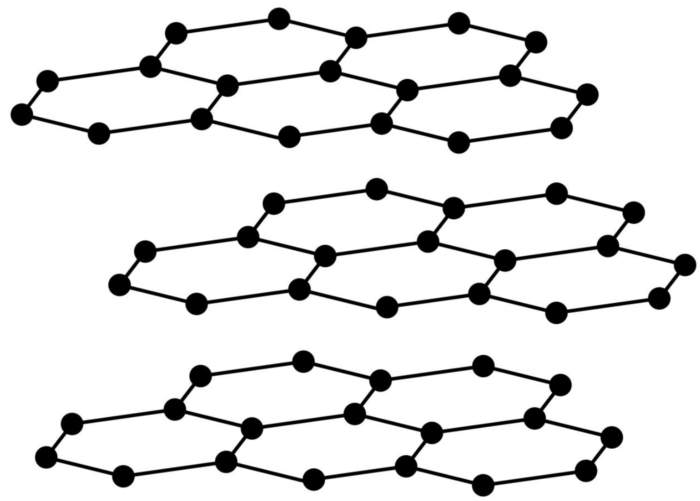
Name (Last, First): ________________________________ ID Number: __________________

# WUCT: Chemistry of Art Sample

1. Carbon, one of the most abundant elements on earth, is not only an essential backbone for life but also a pertinent element in art materials. This question will investigate some of the properties that make carbon so versatile.

   a. Carbon is an art medium can be found even amongst the doodles of your notebook in the form of graphite from pencil lead.



      i. Graphite (shown above) consists of layers of planar carbon latices. Using an argument involving intermolecular forces, explain why graphite can be used for writing and sketching with a pencil.

      While the covalent interactions between the carbon atoms in each sheet are strong, the Van der Waal's interactions between the sheets are relatively weak. Little energy is needed to separate them, making them ideal for writing.

      ii. Given that graphite has a density of 2.266 g/cm$^3$, and that a cylindrical piece of mechanical pencil lead has a diameter of 0.7 mm and a length of 60 mm, calculate the moles of carbon present in the lead. Assume graphite is the only substance present in the lead. ($Volume_{cylinder} = \pi r^2 h$)

      $V_{cyl} = (3.14)(0.035\ cm)^2(6\ cm) = 0.023\ cm^3$
      $(0.023\ cm^3)(2.266\ g/cm^3)(1\ mol / 12.011\ g) = 0.00434\ mol\ graphite$

      iii. You decide to sketch an elaborate self-portrait using the same pencil lead described in a.ii. The original mass of the paper is 4.5 g; however, after finishing the sketch, the mass is not 6.2 g. What is the mass of graphite used in the sketch?

Name (Last, First): ________________________________ ID Number: _________________

6.2 g - 4.5 g = 1.7 g graphite

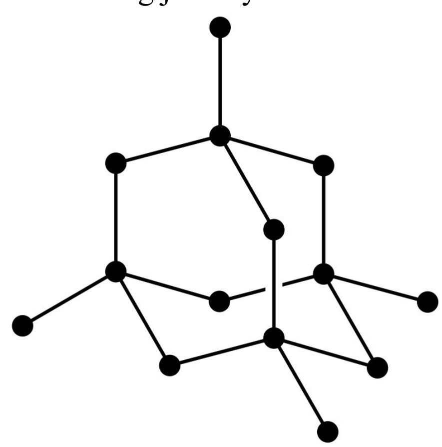
1. After completing the sketch, you want to know how many mechanical pencil leads you would need to recreate the sketch. Using your previous calculations, determine the minimum number of pencil leads needed to make an exact replica of the sketch.

   (1.7 g)(1 mol / 12.011 g)(1 lead / 0.00434 g) = 32.6 leads
   Need a minimum of 33 pencil leads to make the sketch again.

iv. Graphite is also insoluble in water and many organic solvents, making it great for marking chromatography plates and papers. Explain why this is so, using the structure and properties of graphite to support your argument.

The layers of carbon are hydrophobic and will not dissolve in polar solvents very well, so graphite will not dissolve and run up chromatography paper with the solvent front.

b. Under intense heat and pressure, carbon can form diamond instead of graphite, which is commonly used in making jewelry.



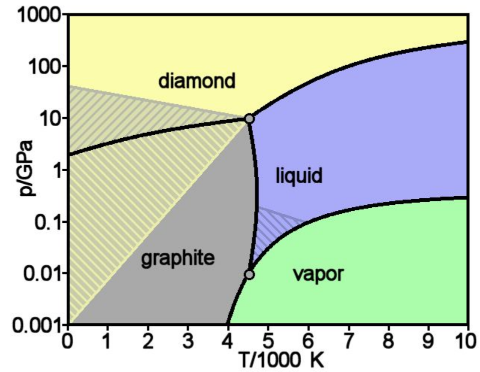
i. Given the structure of diamond (above), state the hybridization and geometry of the carbon atoms in both diamond and graphite (structure in part a.).

Diamond: sp3, tetrahedral
Graphite: sp2, trigonal planar

ii. Despite being both made from carbon, graphite is much more abundant than diamond. Calculate ΔH for the conversion of graphite to diamond if $\Delta H_f$ of graphite is 0.0 kJ and $\Delta H_f$ of diamond is 2.0 kJ.

$\Delta H_{f,\ diamond} - \Delta H_{f,\ graphite}$ = 2.0 kj - 0.0 kj = 2.0 kj

iii. Given the state diagram below, explain why diamond is so much rarer in nature than graphite despite having relatively similar energies.




Diamond requires a large amount of pressure and heat to form, conditions which are rare in nature, while granite is a lot more stable and easily formed in standard conditions.

iv. One reason diamond is popular in jewelry, aside from its looks, is the fact that diamond seemingly lasts forever. This is because $^{12}C$ is a stable, non-radioactive isotope. However, $^{14}C$, a less abundant isotope, will undergo radioactive decay. Given a rate constant k = $3.83 \times 10^{-12}\ s^{-1}$, determine the half-life of 1 equivalent of $^{14}C$.

$t_{1/2} = \ln(2) / k$
$t_{1/2} = \ln(2) / (3.83 \times 10^{-12}\ s^{-1}) = 1.81 * 10^{11}\ s = 5740$ years

v. $^{14}C$ will decay into a stable $^{14}N$ isotope. Nitrogen turns out to be a common contaminate of diamond. Depending on the structure and amount of nitrogen contamination, these diamonds can appear yellow. Explain briefly why the incorporation of nitrogen impurities may result in this difference in color.

When light hits the nitrogen that has been incorporated into the diamond, the nitrogen will absorb blue light, which causes the reflected color to be yellow. This differs from pure diamond which appears clear and colorless.

c. One more use of carbon in art is a bit more "explosive" than the previous examples. More specifically, carbon is an integral part of making fireworks, as the combustion of carbon provides energy to propel the firework.

i. Below is a simplified chemical equation for the combustion of gunpowder. Add stoichiometric coefficients to balance the equation.

10 $KNO_3$ + <u>8</u> C + 3 S → <u>2</u> $K_2CO_3$ + <u>3</u> $K_2SO_4$ + <u>6</u> $CO_2$ + <u>5</u> $N_2$

ii. Saltpeter, a common name for potassium nitrate, is a critical component of this combustion reaction. Looking at the formula of saltpeter and the equation above, why might saltpeter be so important in this combustion?

Saltpeter (potassium nitrate) provides oxygen, which is critical for the combustion reaction and production of energy for propulsion.

iii. Although carbon is present in fireworks, it is not the reason for the vibrant colors we see. Rather, other elements like Strontium and Copper emit photons of various wavelengths when their electrons are excited via heat.

1. Given $Sr^{2+}$ emits a photon with E = 1.77 eV and $Cu^{2+}$ emits a photon of E = 2.53 eV, determine the wavelength in nm and color emitted by each.

$$E_{ph} = h\nu$$

$$2.53\text{eV} * \frac{1.602\text{x}10^{-19}\text{J}}{1\text{eV}} = 4.02\text{x}10^{-19}\text{J} \qquad 1.77\text{eV} * \frac{1.602\text{x}10^{-19}\text{J}}{1\text{eV}} = 2.84\text{x}10^{-19}\text{J}$$

$$4.02\text{x}10^{-19}\text{J} = \frac{(6.626\text{x}10^{-34}\text{J} * \text{s})\left(\frac{2.998\text{x}10^{8}\text{m}}{\text{s}}\right)}{\lambda}$$

$$2.84\text{x}10^{-19}\text{J} = \frac{(6.626\text{x}10^{-34}\text{J} * \text{s})(\frac{2.998\text{x}10^{8}\text{m}}{\text{s}})}{\lambda}$$

$$\lambda \text{ of copper} = 495 \text{ nm}, \quad \lambda \text{ of strontium} = 700 \text{ nm}$$

The emitted light from strontium is red, and the emitted light of copper is blue.

2. Place the emission lines of each element in relation to each other on the spectrum below.